TOTAL MAXIMUM DAILY LOAD (TMDL) DEVELOPMENT

For *NUTRIENT ENRICHMENT* in

WEISS RESERVOIR

(HUC 03150105)

Cherokee County, Coosa River Basin, Alabama

United States Environmental Protection Agency

SUMMARY PAGE

for Nutrient Enrichment TMDL in

Lake Weiss, Alabama

Alabama's final 1998 303(d) list identified Lake Weiss near Centre, Alabama as not supporting its designated use, with the pollutant of concern being nutrient enrichment. This total maximum daily load (TMDL) is being established pursuant to the 1998 Alabama 303(d) list and the Consent Decree in the Alabama TMDL Lawsuit.

Total phosphorus was determined as the nutrient of concern. The TMDL calculation was made using the CE-QUAL-W2 reservoir model. The water quality numeric target was determined to be a 20-ug/l Chlorophyll-a (Chl-a) lake wide average value which is equivalent to a Carlson Trophic State Index (TSI) of 60. This target will allow for sufficient productivity in the reservoir to maintain the fisheries, but on the other hand, reduce the risk of nuisance blooms of algae and reduce the hypolimnetic oxygen deficit, thereby improving fish habitat. Calendar year 1991, an average wet weather year, was targeted to determine what nutrient reductions were needed to meet the 20 ug/l Chl-a target.

Since both phosphorus and nitrogen concentrations impact Lake Weiss Chl-a values and both nutrients are or can be the limiting nutrient, numerous reduction scenarios could be evaluated. For this phase of the TMDL only phosphorus reduction was considered.

For the 1990s, the average growing season (May – October) total phosphorus load to Lake Weiss was 355,000 kg/growing season of which 180,000 kg/growing season is due to upstream point source discharges. To meet the average Chl-a target of 20 ug/l during the targeted 1991 growing season, a 36,000 kg/growing season reduction in phosphorous is needed. This can be accomplished by a 20 percent reduction in the upstream point source phosphorus load. These reductions, from upstream point sources, then result in a total phosphorus load to the Lake of approximately 144,000 kg/growing season and an overall load to the Lake of approximately 319,000 kg/growing season.

Note that stream flow also plays a major role in the Lake Weiss water quality. If the growing season average flows are changed due to additional withdrawals or change in upstream reservoir discharges, the nutrient TMDL will change. If the growing season stream flows increase the allowable total phosphorus load could increase. If the growing season average stream flows decrease, the allowable total phosphorus load TMDL will also decrease.

This TMDL should be considered phase one of a multi-phase TMDL. It is further recommended that future phases include the implementation of a comprehensive watershed and river monitoring effort and the development of a watershed nutrient loading and dynamic river model that will better characterize the relative point and nonpoint source impacts and contributions. This comprehensive study should be timed to correspond with the State's ongoing basin planning and monitoring activities. The State of Alabama, through the data collected via their lakes monitoring program, should re-evaluate the Chl-a target to assure this is the appropriate water quality target to protect the recreation and fishery uses in the reservoir.

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Introduction

Section 303(d) of the Clean Water Act (CWA) as Amended by the Water Quality Act of 1987, Public Law 100-4, and the United States Environmental Protection Agency's (USEPA/EPA) Water Quality Planning and Management Regulations [Title 40 of the Code of Federal Regulation (40 CFR), Part 130] require each State to identify those waters within its boundaries not meeting water quality standards applicable to the water's designated uses. Total maximum daily loads (TMDLs) for all pollutants violating or causing violation of applicable water quality standards are established for each identified water. Such loads are established at levels necessary to implement the applicable water quality standards with consideration given to seasonal variations and margins of safety. The TMDL process establishes the allowable loadings of pollutants or other quantifiable parameters for a water body, based on the relationship between pollution sources and in-stream water quality conditions, so that states can establish water-quality based controls to reduce pollution from both point and nonpoint sources and restore and maintain the quality of their water resources (USEPA, 1991).

Problem Definition

Alabama's final 1998 Section 303(d) list identified 40 miles of Lake Weiss in the Coosa River Basin between the Alabama-Georgia state line to the Lake Weiss powerhouse dam pool as not supporting its designated use as a swimming/fish and wildlife/public water supply water, with the pollutant of concern being nutrient enrichment. The anti-degradation narrative criteria from the Code of Alabama rules and regulations (335-6-10.06 (c), 1991) applies. This listing decision was based on historical routine monitoring data that was collected in Lake Weiss and the data available in the Lake Weiss Phase 1 Diagnostic/Feasibility Study for water years 1991 and 1992 (Bayne 1993).

Target Identification

The target level for the development of the nutrient enrichment TMDL in Lake Weiss is the narrative criterion established in Alabama's Rules and Regulations. Chl-a and the Carlson Trophic State Index (TSI) based on Chl-a were used as the numeric targets. Carlson TSI's (Carlson, 1977) were calculated based on growing season average Chl-a in the photic zone.

The TMDL will be represented by the total growing season (May-Oct) nutrient loads that are allowable so the reservoir achieves a reservoir-wide average Chl-a concentration of 20 ug/l. This target will allow for sufficient productivity in the reservoir to maintain the fisheries, but on the other hand, reduce the risk of nuisance blooms of algae and reduce the hypolimnetic oxygen deficit, thereby improving fish habitat. A 20-ug/l Chl-a lake wide average value provides a Carlson TSI of 60, midway within the defined range of eutrophic waters TSI (50 to 70)(Carlson 1977).

Background

Weiss Reservoir is a major impoundment with significant recreational fishing value to the public in both northeast Alabama and northwest Georgia. In addition, the reservoir serves as a source of water supply for the town of Cedar Bluff in Alabama. Alabama Power Company constructed the reservoir and manages hydroelectric operation with a generating capacity of 87,750 kilowatts.

Lake Weiss was formed when Alabama Power impounded the Coosa River in 1961 for the purpose of hydroelectric power generation. Other major tributaries to Lake Weiss include the Chattooga and Little Rivers. Lake Weiss drains approximately 13,657 square kilometers, most of which is located in northwest Georgia. The dam is a gravity concrete and earth-fill type with a maximum height of 26 meters. The reservoir is located in Cherokee County in northeastern Alabama near the Alabama-Georgia state line. (See Figure 1) The headwaters of the reservoir extend into Floyd County, Georgia. The Alabama towns of Centre, Leesburg, and Cedar Bluff are located in the immediate proximity of Lake Weiss, and the City of Rome, Georgia is located ~27 river miles upstream from the reservoir's headwaters. The reservoir lies in the Coosa Basin in the valley and ridge physiographic province of Northern Alabama. The reservoir at full pool encompasses over 12,000 hectares of surface area and a volume of almost 38,000 hectare-meters. Full pool elevation is 172 meters above mean sea level and average depth of the reservoir is 3.1 meters.

Drawdown of approximately 2 meters occurs from September until December, and the reservoir is allowed to reach full pool again by May. Average hydraulic retention time in the reservoir is ~ 18 days. Lake Weiss typically does not become thermally stratified due to its high flushing rate and relatively shallow average depth. Lake Weiss is chemically well mixed, but vertical gradients in dissolved oxygen are present during the spring, summer, and fall growing seasons.

Alabama Department of Environmental Management water-use classifications for Lake Weiss are:

> **Weiss Dam Powerhouse to Spring Creek –** Public Water Supply/Swimming/Fish and Wildlife
>
> **Spring Creek to state line –** Swimming/Fish and Wildlife

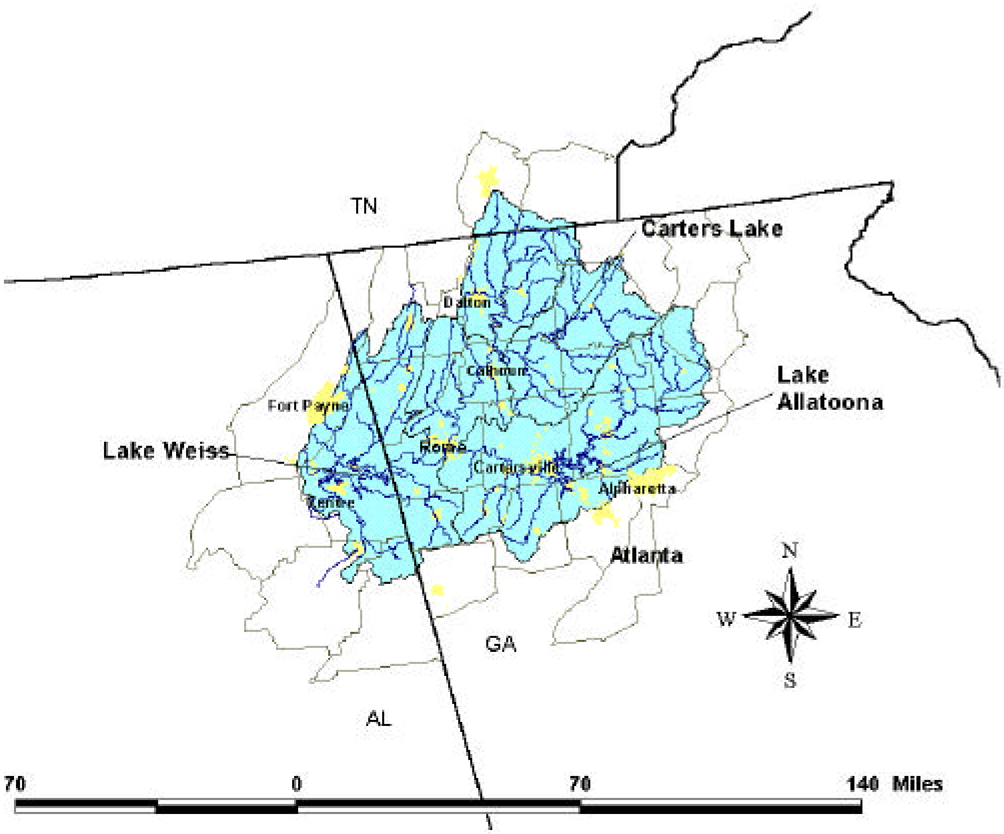

Figure 1 - Lake Weiss Location Map

Available Monitoring Data

EPA Region 4 compiled available monitoring data considered for TMDL development in the report "Summary of Water Quality Data and Information Developed Pursuant to Lake Weiss TMDL Study" (EPA, 2000). This data included reservoir vertical and longitudinal profiles for nutrients, algae, dissolved oxygen, and temperature. Other available data included meteorological, sediment oxygen demand, and algal growth potential test data and additional tributary monitoring conducted by Alabama Department of Environmental Quality (ADEM), Georgia Environmental Protection Division (GaEPD), and the United States Geologic Survey (USGS).

Numeric Targets and Sources

Model Development

The Reservoir Water Quality Model, CE-QUAL-W2 developed by U.S. Army Corps of Engineers Waterways Experimental Station (WES) had been calibrated for 1991 and growing season 1994 by WES. The Alabama-Coosa-Tallapoosa (ACT) Comprehensive Study applied the calibrated model to 1986 meteorology and hydrology. The model was re-calibrated for 1991 by EPA Region 4 to enhance comparison of predicted and observed algae concentration and phosphorous concentration. Details on the model development are contained in the EPA Lake Weiss Calibration Report (EPA 2000).

The calendar year 1991 is an average wet weather year and was used to determine what nutrient reductions were needed to meet the numeric target of a 20-ug/l Chl-a lake wide average value and a Carlson TSI of 60. This target, based on Lake Weiss Phase 1 Diagnostic/Feasibility Study for water years 1991 and 1992 (Bayne 1993) and evaluation of Chl-a data collected by Alabama from 1991 through 1998, was determined to be a reasonable water quality target. This target will allow for sufficient productivity in the reservoir to maintain the fisheries, but on the other hand, reduce the risk of nuisance blooms of algae and reduce the hypolimnetic oxygen deficit, thereby improving fish habitat.

The drought year of 1986 was used to evaluate impacts at critical low flow events. The 1986 model applied by AScI Corporation under contract to the Corps of Engineers (Martin and Hesterlee, 1998) for use in the ACT Study was modified by EPA Region 4 to assume 1991 water quality concentrations superimposed on 1986 inflows, outflows, and meteorology. This data was similar to the boundary conditions used in the ACT Comprehensive Study. Insufficient boundary data existed to use 1986 water quality for TMDL purposes. This drought year is assumed as the critical hydraulic condition for nutrient enrichment as retention is maximized. Average reservoir retention in 1986 (~45 day maximum) is more than double the 1991 maximum retention. In addition, the reservoir maintains only about 75% of the 1991 growing season average volume.

Watershed-wide nutrient loads were estimated by Bayne et al (Bayne 1993) as part of the Lake Weiss Phase 1 Diagnostic/Feasibility Study for water years 1991 and 1992. The USACE-WES computer model FLUX (Walker, 1996) was used to predict loading from the Coosa River and Chattooga River for water years 1993-1998. FLUX was run on all available 1991-1998 water quality data collected at the state line water quality stations in the Coosa and Chattooga Rivers to assess annual total phosphorous loading and to characterize relationships between flows, concentrations, and loads.

Modeling Assumptions

For the purposes of the TMDL, nutrient loads were calculated based on available measured data. Linearly interpolated monthly and bi-monthly measured concentrations are multiplied against daily flow values to estimate the mass flux into the reservoir used for modeling purposes. Concentrations may vary greatly during storm events and the FLUX model (Walker 1996) was run to regress an equation to relate concentrations to flows. Correlation was not strong enough to support this analysis. This was due in part to a lack of storm event monitoring as most monitoring occurred during lower base flow conditions. Additional storm event monitoring is needed to better characterize the overall nonpoint source impacts.

The CE-QUAL-W2 reservoir model uses soluble reactive phosphorus whereas only total phosphorus has been extensively measured in the Coosa River that represents the largest source of phosphorus to the lake. Therefore, for modeling purposes, it was assumed that 100% of the measured total phosphorus in the

Coosa River at the state line was in the form of soluble reactive phosphorus. Further instream and point source phosphorus monitoring is needed to determine the actual fraction that is soluble reactive phosphorous.

Limited flow and nutrient data were available for all the tributaries entering Lake Weiss. The nutrient loads were estimated from nearby monitoring stations for all major tributaries in order to assess the impact of excessive nutrient loading on water quality in Lake Weiss.

Inflow algal concentrations are estimated from chlorophyll-a data. CE-QUAL-W2 models algae as organic matter. Chl-a values in parts per billion can be converted to algae as organic matter as parts per million using the factor of 65 as recommended in the CE-QUAL-W2 User's Manual (Cole and Buchak, 1995).

Due to the above modeling assumptions and limitations, the model is not appropriate for an absolute quantitative assessment of water quality endpoints. The model does succeed in predicting the difference between the average growing season Chl-a values for various nutrient reduction scenarios. Uncertainty represented by the calibration statistics will add uncertainty to the nutrient reduction scenarios.

The computer simulation FLUX did derive a strong correlation, as expected, between load and flow, especially for the nitrogen components. Therefore, as expected the allowable nutrient loads to the Lake to meet the proposed target will vary year-to-year dependent on the flow. The TMDL is being developed for 1991, an average wet weather year.

Total Maximum Daily Load (TMDL)

Critical Condition Determination

Due to Lake Weiss's relatively short retention time, the concept of phosphorus loading is not as important to productivity levels in the reservoir as phosphorus concentrations. High loads associated with high flows tend to flush more rapidly through the reservoir. Sensitivity analyses as well as review of historic data both suggest that Lake Weiss chlorophyll-a levels peak when reservoir hydraulic retention is relatively long. These conditions occur during drought years when inflows and outflows are less and Alabama Power operates the reservoir to maintain pool volume. Nutrient concentrations in the reservoir are conducive to a very productive reservoir, and light limitations as well as hydraulic retention are major controls regarding ultimate productivity in the reservoir.

Lake Weiss is a relatively shallow impoundment with a relatively high surface area to volume ratio. Wet years tend to introduce much higher nutrient loads to the reservoir, but in turn, these high loads are driven rapidly through the reservoir with springtime average hydraulic retention on the order of a week to ten days. Wet years also introduce higher abiogenic (not of biological origin) turbidity and suspended solids in lentic portions of the reservoir, further limiting productivity as the higher velocities help to maintain suspended solids concentrations.

Calendar year 1991 was selected to develop the TMDL because it is an average flow year that includes the impact of wet weather flows and greater nonpoint source impacts and was used to determine what nutrient reductions were needed to meet the numeric target of a 20-ug/l chl-a lake wide average value and a Carlson TSI of 60.

The drought year of 1986 was used to examine nutrient impacts at critical low flow events. Average reservoir retention in 1986 (~45 day maximum) is nearly double the 1991 maximum retention. In addition, the reservoir maintains only about 75% of the 1991 growing season average volume. Limited data was available for 1986; therefore this low flow year was only used to illustrate the change in Chl-a that would occur with the reductions required by the calendar year TMDL. Further monitoring and modeling will be needed to address growing season critical conditions during a low flow critical year.

Seasonal Variation

Reservoir loading analysis reveals that highest nutrient loading occurs during the winter and spring rainy seasons. Due to the short retention time in Lake Weiss, high loads of phosphorus associated with summertime thunderstorms may also enter the reservoir. These high loads associated with elevated flows tend to flush rapidly through the reservoir. Algae concentrations in the mainstem of the reservoir tend to peak during early August, but nuisance blooms have occurred anytime between April and November. This

TMDL will focus on reducing the average concentrations of nutrients in the reservoir during the late spring through early fall growing season. Nutrient loading to the reservoir during wetter months has the potential to impact water quality downstream of Lake Weiss. Further study is needed to evaluate specific storm event flow and nutrient concentration impacts on Lake Weiss. To accomplish this, a watershed and dynamic river model must be developed and combined with the existing reservoir model.

Margin of Safety

The margin of safety in the TMDL considered various conservative assumptions. The model was run for the critical (May through October, 1991) growing season of an average wet weather flow year that takes into account both point source and wet weather nonpoint source contributions and checked against the 1986 drought flow conditions. For modeling purposes, it was assumed that 100% of the measured total phosphorus in the Coosa River at the state line was in the form of soluble reactive phosphorus. For the point sources it is assumed 100 percent of the total phosphorous is soluble reactive phosphorus and 100 percent of the point source phosphorus discharge reaches Lake Weiss for 1991 average wet weather year conditions.

TMDL Determination

Reducing the 1991 nutrient boundary concentrations in the CE-QUAL-W2 model until an average growing season 20 ug/l Chl-a value was predicted throughout the entire reservoir yielded the nutrient reduction needed. Since both phosphorus and nitrogen concentrations impact Lake Weiss Chl-a values and both nutrients are or can be the limiting nutrient, numerous reduction scenarios could be evaluated. For this phase of the TMDL only phosphorus reduction was considered.

For the 1990s, the average growing season (May – October) total phosphorus load to Lake Weiss was 355,000 kg/growing season of which 180,000 kg/growing season is due to upstream point source discharges. To meet the average Chl-a target of 20 ug/l during the targeted 1991 growing season, a 36,000 kg/growing season reduction in phosphorous is needed. This can be accomplished by a 20 percent reduction in the upstream point source phosphorus load. These reductions, from upstream point sources, then result in a total phosphorus load to the Lake of approximately 144,000 kg/growing season and an overall load to the Lake of approximately 319,000 kg/growing season.

TMDL = WLA(wasteload allocation) + LA(Load allocation) + MOS(Margin of safety)

TMDL = 319,000 kg total phosphorus/growing season

WLA = 144,000 kg total phosphorus/growing season

LA = 175,000 kg total phosphorus/growing season

The drought year of 1986 was used to evaluate impacts at critical low flow events and based on an initial analysis, with a 20% reduction in point source loads the Chl-a growing season average should be below 22 ug/l. Again, further study is needed to adequately evaluate the low flow growing season conditions.

Allocation of Responsibility and Recommendations

Point Source Impacts

Based on the Daily Monitoring Reports (DMR), for 1997 through 1999, the point source dischargers contributed 180,000 kg/day over the Lake's growing seasons. This is approximately 50 percent of the phosphorus load to the lake. Point sources have a major impact on the water quality in Lake Weiss both in terms of nutrient impact on Chl-a and the Trophic State Index. Point sources also impact the boundary condition dissolved oxygen concentrations, which in turn affect the dissolved oxygen levels in the Lake, because Lake Weiss has such a low retention time.

To adequately address the point sources and their overall impact on Lake Weiss, watershed and dynamic river models, including all the major rivers in the upstream watershed (with Allatoona and Carters Dams as boundaries) must be developed, along with additional monitoring data to calibrate the models. See Modeling and Monitoring Recommendations Section. Based on these types of analyses, specific wasteload reduction and nonpoint source reduction strategies can be developed to provide the reductions needed to meet the nutrient targets.

However, since some phosphorus reduction is needed, it is also recommended that:

- The 144,000 kg/growing season WLA for phosphorus be incorporated in the next round of upstream point source permits. Upstream point sources are described as those point sources in the Lake Weiss watershed and below Lake Allatoona and Lake Carter outflows.

- Detailed phosphorus monitoring of the point sources should continue: and
- No increase in existing point source phosphorus loading be allowed until point source permits are revised and/or the watershed and river modeling and the WLA reduction strategies are finalized.

As the State of Alabama collects further information on Lake Weiss through their lakes monitoring program, the Chl-a target will be continually re-evaluated to assure this is the appropriate water quality target to protect the recreation and fishery uses in the reservoir.

Non-Point Source Impacts

Wet weather sampling in the Coosa River and the major tributaries in the Lake Weiss watershed is needed to determine background and non-point source components of the load allocation. Special monitoring above and below the City of Dalton's wastewater land application system is needed to define its contribution to the over-all phosphorus load.

Monitoring and Modeling Recommendations:

All monitoring activities should be coordinated with the Alabama and Georgia River Basin monitoring activities. Alabama is conducting detailed sampling of Lake Weiss this year and Georgia will be conducting Coosa River Basin basin-wide monitoring in 2001.

Specific monitoring recommendations include:

- Sample, monthly and twice monthly during growing season, the nutrient concentration (ortho-phosphorus, total phosphorous, nitrite/nitrate, ammonia, total nitrogen), dissolved oxygen (D.O.), TSS, total organic carbon (TOC), corrected Chl-a, and temperature in:

  - The Coosa River and Chattooga River at the Weiss boundary stations,
  - Downstream of Allatoona and Carters dams, and
  - The mouth of each major tributary.

- Sample intensively during multiple storm events to develop relationships between nutrient concentrations and flows.
- Require all relevant major (1MGD or greater) permitted dischargers to measure and report ortho-phosphorus, total phosphorous, nitrite/nitrate, ammonia, total nitrogen, D.O., TSS and TOC average and maximum monthly concentrations/loads.

Develop non-point source loading models in all subwatersheds draining into Lake Weiss except for those upstream of the Allatoona and Carter dams.

Measure Lake Weiss outflow temperatures and DO to improve hydrothermal and water quality CE-QUAL-W2 calibration. Re-calibrate the model using current year's Lake data (drought year) and year 2001 watershed monitoring data for model verification. This will require water quality profiles of nutrient concentration (ortho-phosphorus, total phosphorous, nitrite/nitrate, ammonia, total nitrogen), DO, TSS, TOC, corrected Chl-a, and temperature collected at a frequency interval greater than the average hydraulic retention time of the growing season being modeled.

The relationship between reservoir hydraulic retention and reservoir productivity needs to be explored further due to strong correlation between these parameters.

Watershed nutrient model and dynamic river models of the Coosa and Chattooga systems need to be developed. These models should encompass the entire Lake Weiss watershed from Allatoona and Carters Dams on down to the Lake Weiss Dam. The ACT Comprehensive Study modeling effort can be used as a starting point but a more rigorous and detailed modeling approach is necessary for WLA and TMDL development.

Schedules for the Next Phases of the TMDL:

Phase 2: Lake Weiss Drought flow analysis. During growing season 2000 (drought year), Alabama will collect additional Lake Weiss data. In 2001 EPA will conduct review of drought-growing season water quality data and 2001 water quality data (October 2001).

Phase 3: Lake Weiss watershed modeling and updated Lake Weiss modeling. In 2001 Georgia, Alabama and EPA will conduct watershed monitoring and Alabama will continue Lake Weiss monitoring. By June 2003, the watershed and river modeling will be completed and TMDL completed by June 2004.

Flow Recommendations:

Any changes in the "normal" flow patterns or reductions in flow values will need to be mitigated with a corresponding reduction in the nutrient TMDL values.

Coosa River Dissolved Oxygen Concentrations:

An important factor in the dissolved oxygen regime of Lake Weiss is the Coosa River D.O. levels as they enter Lake Weiss. A dynamic stream model will be needed to evaluate these daily variations in D.O. and the impact of upstream point sources.

It is recommended that the immediate upstream point source oxygen demanding loads be held at existing loads.

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